Force-sensorless robot force control within the instantaneous task specification and estimation (iTaSC) framework[1]

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1 Introduction

Many service-robot applications, such as robotic table wiping, require force control with only limited precision. In backdrivable robots, a force-sensorless robot control scheme can be applied to avoid the integration of expensive force sensors in the already complex hands. Next to tasks involving a force control scheme, the robot has to fulfill other tasks using the same robot joints. Therefore, the lower level controllers can't be altered, resulting in a force control scheme around the existing lower level controllers. Vanthienen et al. [1] demonstrated the instantaneous Task Specification and estimation using Constraints (iTaSC) approach to a force-sensorless and bimanual human-robot comanipulation task, using a simple sensorless wrench-nulling control scheme in free space. This iTaSC framework [2] is a constraint-based framework that uses particular sets of auxiliary coordinates to express task constraints and model geometric uncertainty. It describes a robot task as an optimization problem consisting of a set of constraints and one or multiple objective functions. This presentation extends the force-sensorless control scheme in iTaSC with a contact model and a setpoint input, to be able to apply a desired non-zero contact force in a controlled way. Our approach studies in depth the control scheme for the one degree-of-freedom case in free space and in contact as well as the transition between both. Further it extends the control scheme to the multi degree-of-freedom case in iTaSC. The multi degree-of-freedom case considers a prioritized, weighted damped least-squares optimization problem solver, resulting in the desired robot joint velocities that are the control input for the lower level joint velocity controllers of the robot.

2 Methodology

Figure 1 depicts the one degree-of-freedom robot force control scheme. It shows the robot system model and lower level joint velocity controller in red, the stifness model of the contact with the environment in green, and the part of the controller that can be designed in blue. Remark that there is no gravity term in the model, since the PR2 robot arms, used in the experiments are mechanically gravity-compensated. In the free space scenario, i.e. without the contact model,

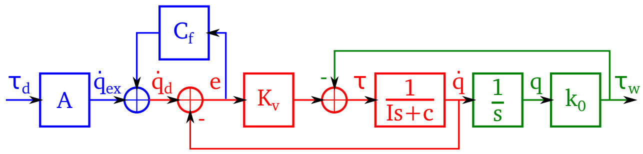

Figure 1: One degree-of-freedom robot force control scheme

the model describes a first order system with as input the desired torque τ_d and as output the joint velocity $\dot{q}$. In the contact scenario, i.e. including the contact model, the model describes a second order system with as input τ_d and as output the torque τ_w exerted on the environment. Remark that the velocity error is used as a torque measure [1]. When extending the scheme to the multi degree-of-freedom case, the abovementioned variables become vectors and constants become matrices. The contact model, as well as the higher level control and desired wrench w_d are in task space, requiring transformations between the task and robot joint space.

3 Analysis and experimental results

The joint velocity error feedback constant C_f has as effect the adaption of the velocity loop feedback constant K_v, to an equivalent velocity loop feedback constant $\frac{K_v}{1-C_f}$. In the multi degree-of-freedom case, not all robot joints and segments are the same, hence their models will differ as well as their lower level velocity loop constants K_v. The control scheme neglects joint coupling effects, since the higher level tasks have slow dynamics, compared to the high bandwith lower level velocity loop. Experiments on a PR2 robot validate the proposed control scheme. In the experiments, the robot has to apply a force to a table in order to wipe it. The one degree-of-freedom simulations and the experimental validation show that there exists a control gain C_f that results in satisfactory control bandwidth, precision of the applied force, and that remains stable for both the free space and contact scenario.

References

[1] D. Vanthienen, et al. "Force-Sensorless and bimanual human-robot comanipulation," SYROCO 2012.

[2] J. De Schutter, et al. "Constraint-Based Task Specification and Estimation for Sensor-Based Robot Systems in the Presence of Geometric Uncertainty," IJRR 2007.

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